RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS (DO-282), Revision A

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Proposed Changes to DO-282 to accommodate an Optional Diplexer

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SUMMARY
This Working Paper contains suggested text for the proposed additional requirements and related test procedures for the Diplexer.

1.0 Purpose And Scope

2.0 Equipment Performance Requirements and Test Procedures

2.1 General Requirements

2.2 Equipment Performance – Standard Conditions

2.2.1 Definition of Standard Conditions

2.2.2 ADS-B Transmitter Characteristics

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2.2.14.1 Polarization

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2.2.14.3 Optional Diplexer Requirements

An option to use a frequency diplexer is provided to allow sharing of a single antenna between the ATCRBS/Mode S Transponder and the UAT unit is provided herein. Sharing a common antenna between the two systems may be desirable in aircraft to minimize antenna installation cost and complexity. The diplexer specified herein is a

three port component which provides connectivity from the UAT port to the antenna port (UAT Channel) and connectivity from the ATCRBS/Mode S port (Transponder Channel) to the antenna port. The UAT Channel frequency response requirements insure adequate passband bandwidth around the 978 MHz UAT frequency to insure that UAT signal integrity is maintained through the UAT unit, diplexer and antenna path. Likewise, the Transponder Channel frequency response requirements insure adequate passband bandwidth around the 1030 MHz and 1090 MHz frequencies to insure that interrogation and reply signal integrity is maintained through the transponder, diplexer and antenna path. The diplexer characteristics insure that performance of both the UAT and Transponder systems is equivalent to their performance without the diplexer with the exception of the attenuation and delay of signal through the diplexer. The insertion loss and delay characteristics of the diplexer must be taken into consideration when determining cable loss and cable delay budgets between the UAT unit and antenna and the Transponder and the antenna. Other installation issues are discussed in §3.2.1.10 along with further guidance to insure proper installation and operation of the systems. Additional diplexer information is available in Appendix E. The use of the diplexer does not preclude the UAT from driving the suppression bus during UAT transmissions. Diplexer installations must include connection and use of the suppression bus driven by the UAT and received by the Transponder as specified in §2.2.12.

2.2.14.3.1 Diplexer RF Requirements

2.2.14.3.1.1 UAT Channel

The diplexer shall include a UAT Channel that conveys UAT signals without distortion of the waveform. The UAT Channel shall convey UAT Basic, Long and Ground Uplink Messages while maintaining the modulation accuracy of the input UAT signals as specified in §2.2.2.4 and produce no more than .5 dB amplitude attenuation and no more than 10 nanoseconds in propagation delay. The UAT Channel shall provide a passband from no greater than 977 MHz to no less than 979 MHz and a maximum attenuation of 0.5 dB. The minimum and maximum attenuation in the passband shall be different by no greater than 0.20 dB. The UAT port of the diplexer shall be capable of peak power transmissions according to the appropriate aircraft equipage class given by Table 2-1. The VSWR produced by the diplexer at the UAT port, when the other two ports are terminated in a 50 ohm transmission line, shall not exceed 1.3:1 for frequencies within the passband.

2.2.14.3.1.2 Transponder Channel

The diplexer shall include a Transponder Channel that conveys 1030 MHz interrogation and 1090 MHz reply signals without distortion of the waveform. The Transponder Channel shall convey pulses that are amplitude modulated on either 1030 MHz or 1090 MHz and having rise and fall times of 50 nanoseconds or more and produce no more than .5 dB amplitude attenuation and no more than 10 nanoseconds delay while retaining the pulse rise and fall times and pulse width of the input pulses. The Transponder Channel shall provide a passband from no greater than 1015 MHz to no less than 1105 MHz and a maximum attenuation of 0.5 dB. The minimum and maximum attenuation in the passband shall be different by no greater than 0.20 dB. The Transponder port shall be capable of handling 1000 Watts instantaneous power. The VSWR produced by the diplexer at the Transponder port, when the other two ports are terminated in a 50 ohm

transmission line, shall not exceed 1.3:1 for frequencies within the passband. If required by the transponder installation, the diplexer shall support DC coupling from the Transponder port to the antenna port as required by the electrical characteristics of the installed equipment.

2.2.14.3.1.3 Channel to Channel Isolation

The diplexer shall provide RF isolation between the UAT Channel and the Transponder Channel. The diplexer shall provide a minimum of 55 dB of isolation between the ports at 1090 MHz. Additionally, the diplexer shall provide a minimum isolation of 40 dB between the UAT and Transponder ports of the diplexer at 1030 MHz. The diplexer shall provide a minimum of 25 dB of isolation between the ports at 978 MHz.

Note: Installations that incorporate the diplexer must insure that the off frequency power seen by the front end of the UAT equipment and the ATCRBS/Mode S transponders through the diplexer are within the design tolerances of each unit to insure proper operation. It has been determined that the isolations provided above should insure safe operation for most transponder designs with respect to off frequency effects. The design of the UAT needs to consider the power seen at the input from the transponder and it should be verified that the transponder design can handle the UAT power through the isolation provided.

2.3 Equipment Performance – Environmental Conditions

2.3.1 Environmental Test Conditions

2.3.2 Detailed Environmental Test Procedures

2.4 Equipment Test Procedures

2.4.1 Definition of Standard Conditions of Test

2.4.2 Verification of ADS-B Transmitter Characteristics (§2.2.2)

2.4.3 Verification of Broadcast Message Characteristics (§2.2.3)

2.4.4 Verification of The ADS-B Message Payload (§2.2.4)

2.4.5 Verification of Procedures for Processing of Time Data (§2.2.5)

2.4.6 Verification of Procedures for ADS-B Message Transmission (§2.2.6)

2.4.7 Verification of UAT Transmitter Message Data Characteristics (§2.2.7)

2.4.8 Verification of Receiver Characteristics (§2.2.8)

2.4.9 Verification of Report Assembly Requirements (§2.2.9)

2.4.10 Verification of Receiver Subsystem Capacity and Throughput Requirements (§2.2.10)

2.4.11 Verification of Special Requirements for Transceiver Implementations (§2.2.11)

2.4.12 Verification of Suppression Requirements (§2.2.12)

2.4.13 Verification of Self Test and Monitors (§2.2.13)

2.4.14 Verification of Antenna System (§2.2.14)

2.4.14.1 Verification of Polarization (§2.2.14.1)

2.4.14.2 Verification of Antenna Voltage Standing Wave Ratio (VSWR) (§2.2.14.2)

2.4.14.3 Verification of Optional Diplexer Requirements (§2.2.14.3)

2.4.14.3.1 Verification of Diplexer RF Requirements

2.4.14.3.1.1 Verification of UAT Channel

Purpose/Introduction:

The diplexer **shall** provide a UAT Channel that conveys UAT signals without distortion of the waveform. The UAT Channel shall convey UAT Basic, Long and Ground Uplink Messages while maintaining the modulation accuracy of the input UAT signals as specified in §2.2.2.4 and produce no more than 0.5 dB amplitude attenuation and no more than 10 nanoseconds in propagation delay. The UAT Channel **shall** provide a passband from no greater than 977 MHz to no less than 979 MHz and a maximum attenuation of 0.5 dB. The minimum and maximum attenuation in the passband shall be different by no greater than 0.20 dB. The UAT port of the diplexer **shall** be capable of peak power transmissions according to the appropriate aircraft equipage class given by Table 2-1. The VSWR produced by the diplexer at the UAT port, when the two other ports are terminated in a 50 ohm transmission line, shall not exceed 1.3:1 for frequencies within the passband.

Equipment Required:

The tests performed in this subparagraph require the diplexer under test, equipment as described in §2.2.8.2.3.a and §2.2.8.2.3.b, two lengths of 50 ohm cable with connector adaptors, a 50 ohm termination, 20 to 30 dB of power attenuation, and a High Power UAT message source with enough power output to surpass the requirements of the equipage class under test. Also, provide a means for measurement of VSWR.

Measurement Procedures:

Step 1: Equipment Setup (§2.2.14.3.1.1)

Connect both cables in series directly between the Signal Generator and the Vector Signal Analyzer temporarily bypassing the diplexer. Configure the

Signal Generator to sweep CW RF with a sweep range of 3 MHz centered at 978 MHz. Configure the Vector Signal Analyzer to display the continuous peak hold of a RF spectrum 3 MHz wide centered at 978 MHz and signal levels between –29.9 and –31.9 dBm.

Step 2: Test Setup (§2.2.14.3.1.1)

Adjust the Signal Generator so that the Vector Signal Analyzer measures a level of –30 dBm, and insure that the difference between the maximum and minimum level across the 3 MHz band is less than 0.05 dB. Insert the diplexer between the two cables at the UAT and Antenna ports, and terminate the Transponder port in 50 ohms.

Step 3: Maximum UAT Channel Passband Attenuation and Ripple (§2.2.14.3.1.1)

Allow the Vector Signal Analyzer to record the results of a number of sweeps sufficient to show smooth results, and verify 1) that the minimum signal level in the 978 MHz +/- 1 MHz range is no less than –30.5 dBm, and 2) that the maximum minus minimum level in the 3 MHz band is no greater than 0.2 dB.

Step 4: UAT Signal Verification (§2.2.14.3.1.1)

Get ready to replace the Signal Generator with the UAT message source, place attenuation between the diplexer and the Vector Signal Analyzer to limit the power into the Vector Signal Analyzer to less than +25 dBm, replace the Signal Generator with the UAT message source, set it to the maximum power for the equipage class under test.

Setup the Vector Signal Analyzer as described in §2.4.2.4 except adjust for the signal levels specified above in this test, and verify that the measured "Eye Diagram" is similar to the one measured in §2.4.2.4, Step 2, and that it shows no distortion of the UAT waveform.

Step 5: UAT Signal Verification - Loss and Delay (§2.2.14.3.1.1)

Determine the power loss of the pulse from the UAT port to the Antenna port, and verify that the loss is no more than 0.5 dB.

Determine the pulse delay measured from the lead edge time of the pulse at the UAT port to the lead edge of the pulse at the Antenna port, and verify that the delay introduced by the diplexer is no more than 10 nanoseconds.

Step 6: VSWR at 978 MHz (§2.2.14.3.1.1)

Verify that the VSWR at the UAT port, with the other two ports terminated in 50 ohms, is no more than 1.3:1 at 978 1030 MHz.

2.4.14.3.1.2 Verification of Transponder Channel

Purpose/Introduction:

The diplexer **shall** provide a Transponder Channel that conveys 1030 MHz interrogation and 1090 MHz reply signals without distortion of the waveform. The Transponder Channel shall convey pulses that are amplitude modulated on either 1030 MHz or 1090 MHz and having rise and fall times of 50 nanoseconds or more and produce no more than .5 dB amplitude attenuation and no more than 10 nanoseconds delay while retaining the pulse rise and fall times and pulse width of the input pulses. The Transponder Channel **shall** provide a passband from no greater than 1015 MHz to no less than 1105 MHz and a maximum attenuation of 0.5 dB. The minimum and maximum attenuation in the passband shall be different by no greater than 0.20 dB. The Transponder port **shall** be capable of handling 1000 Watts instantaneous power. The VSWR produced by the diplexer at the Transponder port, when the other two ports are terminated in a 50 ohm transmission line, shall not exceed 1.3:1 for frequencies within the passband. If required by the transponder installation, the diplexer **shall** support DC coupling from the Transponder port to the antenna port as required by the electrical characteristics of the installed equipment.

Equipment Required:

The tests performed in this subparagraph require the diplexer under test, equipment as described in §2.2.8.2.3.a and §2.2.8.2.3.b, two lengths of 50 ohm cable with connector adaptors, a 50 ohm termination, at least 35 dB of power attenuation, and an RF Signal Source with Pulse Amplitude Modulation at both 1030 and 1090 MHz Carrier Frequencies and at least 1000 Watts of power output. Also, provide a means for measurement of VSWR.

Measurement Procedures:

Step 1: Equipment Setup (§2.2.14.3.1.2)

Connect both cables in series directly between the Signal Generator and the Vector Signal Analyzer temporarily bypassing the diplexer. Configure the Signal Generator to sweep CW RF with a sweep range of 100 MHz centered at 1060 MHz. Configure the Vector Signal Analyzer to display the continuous peak hold of a RF spectrum 100 MHz wide centered at 1060 MHz and signal levels between –29.9 and –31.9 dBm.

Step 2: Test Setup (§2.2.14.3.1.2)

Adjust the Signal Generator so that the Vector Signal Analyzer measures a level of –30 dBm, and insure that the difference between the maximum and minimum level across the 100 MHz band is less than 0.05 dB. Insert the diplexer between the two cables at the Transponder and Antenna ports, and terminate the UAT port in 50 ohms.

Step 3: Maximum Transponder Channel Passband Attenuation and Ripple (§2.2.14.3.1.2)

Allow the Vector Signal Analyzer to record the results of a number of sweeps sufficient to show smooth results, and verify 1) that the minimum signal level in the 1015 to 1105 MHz (central 90 MHz) range is no less than –30.5 dBm,

and 2) that the maximum minus minimum level in the central 90 MHz band is no greater than 0.2 dB.

Step 4: Pulse Input Verification (§2.2.14.3.1.2)

Get ready to replace the Signal Generator with the RF source providing a 450 nanosecond pulse with 50 nanosecond rise and fall times pulse modulated at 1030 MHz. Place attenuation between the diplexer and the Vector Signal Analyzer to limit the power into the Vector Signal Analyzer to less than +25 dBm, and replace the Signal Generator with the RF source.

Setup the Vector Signal Analyzer in vector mode in order to measure the envelope of the RF pulse, and verify that the measured pulse has a 450 nanosecond pulse width and 50 nanosecond rise and fall times.

Step 5: RF Pulse Input Verification – Loss and Delay (§2.2.14.3.1.2)

Determine the power loss of the pulse from the Transponder port to the Antenna port, and verify that the loss is no more than 0.5 dB.

Determine the pulse delay measured from the lead edge time of the pulse at the Transponder port to the lead edge of the pulse at the Antenna port, and verify that the delay introduced by the diplexer is no more than 10 nanoseconds.

Step 6: RF Pulse Input Verification at 1090 MHz (§2.2.14.3.1.2)

Repeat Steps 4 and 5 above with the input RF signal source set at 1090 MHz.

Step 7: VSWR at 1030 MHz and 1090 MHz (§2.2.14.3.1.2)

Verify that the VSWR at the Transponder port, with the other two ports terminated in 50 ohms, is no more than 1.3:1 for both 1030 MHz and 1090 MHz.

2.4.14.3.1.3 Verification of Channel to Channel Isolation

Purpose/Introduction:

The diplexer shall provide RF isolation between the UAT Channel and the Transponder Channel. The diplexer shall provide a minimum of 55 dB of isolation between the ports at 1090 MHz. Additionally, the diplexer shall provide a minimum isolation of 40 dB between the UAT and Transponder ports of the diplexer at 1030 MHz. The diplexer shall provide a minimum of 25 dB of isolation between the ports at 978 MHz.

Equipment Required:

The tests performed in this subparagraph require the diplexer under test, equipment as described in §2.2.8.2.3.a and §2.2.8.2.3.b, two lengths of 50 ohm cable with connector adaptors, and a 50 ohm termination.

Measurement Procedures:

Step 1: Equipment Setup (§2.2.14.3.1.3)

Connect both cables in series directly between the Signal Generator and the Vector Signal Analyzer temporarily bypassing the diplexer. Configure the Signal Generator to sweep CW RF with a sweep range of 150 MHz centered at 1035 MHz. Configure the Vector Signal Analyzer to display the continuous peak hold of a RF spectrum 150 MHz wide centered at 1035 MHz and signal levels between –29.9 and –31.9 dBm.

Step 2: Test Setup (§2.2.14.3.1.3)

Adjust the Signal Generator so that the Vector Signal Analyzer measures a level of –30 dBm, and insure that the difference between the maximum and minimum level across the 150 MHz band is less than 0.05 dB. Insert the diplexer between the two cables at the UAT and Transponder ports, and terminate the Antenna port in 50 ohms.

Step 3: Minimum UAT and Transponder Channel Isolation (§2.2.14.3.1.3)

Allow the Vector Signal Analyzer to record the results of a number of sweeps sufficient to show smooth results, and verify 1) that the maximum signal level in the 978 MHz +/- 1.5 MHz range is no greater than –55.0 dBm, 2) that the maximum signal level at 1030 MHz is no greater than –70.0 dBm, and 3) that the maximum signal level at 1090 MHz is no greater than –85.0 dBm.

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3.1.11 Mutual Suppression

UAT ADS-B equipment is not required to interface with mutual suppression systems.

Replace with:

UAT ADS-B equipment shall interface to the mutual suppression bus. The UAT shall drive the mutual suppression bus during UAT transmissions so that other L Band systems installed in the aircraft can desensitize their receivers during UAT transmissions. Installations with ATCRBs or Mode S transponders shall insure that the transponder is connected to the mutual suppression bus to prevent unsolicited replies from being generated by the transponder during UAT transmissions. UAT equipment shall not receive from the mutual suppression bus.

3.2

3.2.1 Antenna Installation

3.2.1.1 General Considerations

Antenna gain and pattern characteristics are major contributors to the system data link performance. The location and number of antennas required for aircraft ADS-B systems is determined by the equipage class. Classes A1L, A1H, A2, and A3 require antenna diversity and must have transmit and receiving capability on both the top and bottom of the aircraft. Exceptions may be made for installations on radio-transparent airframes. Class A0 installations do not require antenna diversity. Compliance of the installed antennas with the requirements of §2.1.11 may be demonstrated by analysis.

If the ADS-B Transmitting Subsystem shares antennas with a Mode-S transponder, the antennas shall comply with the requirements of RTCA Document Number DO-181B.

Delete above paragraph and replace with:

If the ADS-B Transceiver shares antennas with a Mode S transponder, the antennas shall additionally comply with the requirements of RTCA Document Number DO-181B and the diplexer shall comply with the requirements of §2.2.14.3 of this document.

3.2.1.2

3.2.1.3

3.2.1.4

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3.2.1.6

3.2.1.7

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3.2.1.10 Antenna Diplexer

An antenna diplexer may be utilized in installations with SSR ATCRBs transponders or Mode S transponders to allow antenna sharing of the UAT equipment and the transponder. The use of a diplexer may be considered in all classes of UAT equipage classes. The ATCRBS or Mode S transponder shall conform to the appropriate standards with the use of the diplexer. The installation of a diplexer must consider the impact to the transponder and UAT equipment. The loss of signal power through the diplexer must be factored into the cable loss allocation between the antenna and the transponder and the antenna and the UAT equipment. The signal delay through the diplexer must also be considered and if diversity is supported, the use of a diplexer on the top, bottom or both antenna must insure that the diversity delay tolerances between top and bottom antenna are met for both the transponder and UAT equipment. The characteristics of the diplexer contained in these MOPs should insure proper operation of UAT equipment with the majority of existing models of ATCRBs and Mode S transponders. Extensive testing was performed with current representative ATCRBs and Mode S transponders and prototype diplexers to verify proper operation of the transponders and UAT equipment with the use of a diplexer. Results of these tests were utilized to produce and validate the diplexer requirements contained in this document. The assumptions used to derive diplexer characteristics have taken into consideration existing installations of ATCRBs and Mode S transponders. The loss budget for cable loss between the antenna and equipment in most installations should readily absorb the loss allocated to the diplexer. Variation in diplexer characteristics from the requirements contained in this document must insure that the transponder meet the requirements of the appropriate applicable standard and UAT equipment adhere to this MOPs. Verification that the isolation requirements of the transponder are satisfied and receiver tolerance to high power off frequency signals need to be factors in consideration of use of a diplexer in installations.